Paleoseismology of the Central Calaveras Fault at Halls Valley, Alum Rock, California

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Investigations Undertaken

This research tests the hypothesis that the northwest-striking central Calaveras fault only releases strain through aseismic creep and moderate (**M**≤6.2) earthquakes and not large (**M**≥6.5) earthquakes that may produce surface fault rupture. Our approach addresses this hypothesis by investigating Holocene deposits and landforms in Halls Valley, a small fault-controlled pull-apart basin in the Diablo Range east of San Jose, California. These landforms lie along a series of secondary faults that appear to be locked, and thus may be related to surface fault rupture rather than aseismic creep. Our trench site in Joseph D. Grant County Park lies within a north-trending linear trough that defines the northwestern boundary of a 1- to 1.5-km-wide releasing stepover in the central Calaveras fault system. Geomorphic characteristics of the secondary faults include two vernal pools within a north-trending, linear depression defined by tonal and vegetation lineaments on the east and a prominent east-facing scarp on the west. Although measurements of a local geodetic array indicate that historical creep occurs on faults that bound the eastern and western margins of Halls Valley (Prescott et al., 1984), field reconnaissance found no evidence for historical offset of cultural features on secondary strands of the fault system. Our recent mapping (Witter et al., 2003) shows that the site contains youthful fault-related geomorphic features, an obliquely oriented secondary fault with respect to the regional fault trend, and an absence of evidence for historical aseismic creep away from the main fault trace. These data leave open the possibility that the fault's behavior is not limited to aseismic creep, and that late Holocene geomorphic features along secondary faults may be indicative of surface fault rupture rather than aseismic creep.

In October 2003, we excavated a 56-m-long trench across the eastern slope and floor of the north-trending linear trough at Grant County Park, as a first reconnaissance step in addressing the fault’s behavior. The exploratory trench was located directly north of a local drainage divide to prevent potential sediment transport into a nearby vernal pool along the fault. Stratigraphic and structural relations of the primary fault zone were documented by ~1:20-scale logs of both trench walls. The entire trench was logged at an approximate scale of 1:40. A topographic survey of the immediate area around the trench was completed using an electronic theodolite. After USGS scientists, local consultants, CGS personnel and other interested parties reviewed the trench, we backfilled the trench, restored the site to original grade, and reseeded the entire area with native grass seed provided by the Park.

Results

The preliminary results of the investigation show evidence for reverse displacement on two faults that strike N 20° to 40° W and dip 47° to 56° NE. Both faults cut probable late Pleistocene colluvial deposits that locally mantle Franciscan greywacke. Slickensides on the fault planes indicate pure dip-slip movement. The minimum vertical separation of the base of Pleistocene colluvium ranges from 0.6 to 1.0 m. We interpret that the most recent event vertically displaced a probable late Pleistocene soil developed in the colluvium by approximately 0.3 m. Possible evidence for surface rupture during the most recent event includes a colluvial wedge derived from material in the hanging wall and multiple fault strands that terminate beneath colluvium that buries the scarp. Because we interpret the colluvial wedge to be early to middle Holocene in age, we infer a similar age for the time of the most recent deformation event. Cross-cutting relationships among probable late Pleistocene soils developed in older deposits indicate at least one and possibly two prior events but provide no information to assess whether fault movement involved surface rupture or creep. The youngest colluvial deposits showed no evidence of displacement or deformation above the fault, suggesting that this fault has not experienced aseismic creep since the most recent deformation event. There is no evidence within this trench that can conclusively be attributed to aseismic fault creep.

The orientation and style of faulting evident in the trench exposure is contrary to our regional kinematic model developed from our surficial geologic and geomorphic mapping of the central Calaveras fault (Witter et al., 2003), from which we would expect right-stepping transtensional deformation. We propose two possible explanations for the unexpected fault geometry and slip direction revealed in the trench that likely reflect local stress perturbations along the fault. First, secondary reverse faults that bound pop-up structures near the ends of pull-apart basins have been observed in analog models and natural examples of releasing stepovers along strike slip faults (Dooley and McClay, 1997). The structural style of the reverse faults documented at Halls Valley, their location, and the hill to the east of the faults that may reflect a local pop-up structure, are similar to the simulated geometry and kinematics observed for analog models of pull-apart basins. Alternatively, contractional deformation east of the central Calaveras fault is consistent with the westward transfer of slip onto the southern Hayward fault system. It is possible that pure reverse slip is partitioned onto reverse faults observed at the northern end of Halls Valley to accommodate contractional strain that arises from the left-stepover geometry between the central Calaveras and southern Hayward faults.

Non-technical Summary

This research is designed to test the hypothesis that strain release on the central Calaveras fault occurs solely by aseismic creep and small to moderate earthquakes. To test the hypothesis, we excavated a trench across a north-trending linear trough filled with material shed from nearby hills. We documented geologic relations exposed in the trench walls that provide possible evidence for two or three earthquakes that produced surface deformation. Each earthquake may have produced approximately 0.3 m of vertical displacement on a reverse fault observed in the trench. The most recent event probably occurred several thousand years ago and appears to have involved rupture of the ground surface based on evidence of a buried and degraded fault scarp and fault strands that do not break the youngest deposits in the trench. Also, we found no evidence for slow slip (fault creep) that did not involve large earthquakes since the most recent event. The orientation and style of faulting encountered in this investigation reflect complex patterns of deformation near the northwestern end of Halls Valley related to two possible explanations: (1) a right jog in the regional trend of the central Calaveras fault; or (2) the transfer of slip to the northwest onto the southern Hayward fault system.

Reports Published

None to date.

References

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Data Availability

Additional data, including trench logs and a topographic site map, are available from the authors who may be contacted at the address listed above.